RESEARCH DEPARTMENT

THE EFFECT OF THE SOUND MODULATION SYSTEM UPON THE MONOCHROME RECEPTION OF NTSC-TYPE COLOUR TELEVISION SIGNALS

Report No. T-087

(1962/3)

THE BRITISH BROADCASTING CORPORATION
ENGINEERING DIVISION

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SUMMARY

This report describes tests carried out to assess the sound-signal rejection required in the vision circuits of a monochrome receiver tuned to an NTSC-type colour emission accompanied by either a.m. or f.m. sound signals. It is shown that the required sound-trap attenuation is not significantly different for the two systems.

1. INTRODUCTION

It has been general practice in the U.S.A. and on the Continent, where television systems employ frequency-modulation for the sound signals, to design monochrome receivers with a sound-trap attenuation of some 26 dB,[1] relative to the flat portion of the main-sideband response. In this country, where amplitude-modulation is used for the sound signals, it has been necessary to provide attenuation of at least 40 dB at the sound-carrier frequency. The increased attenuation is required in order to reduce the cross-modulation effects of the a.m. sound components at the vision detector.

With colour transmissions of the type employing a band-sharing sub-carrier to convey the chrominance information, an additional signal will be present, which, owing to the use of envelope detection, will result in the appearance of intermodulation components at the vision-detector output. These additional components will have frequencies equal to the sum of and difference between the sub-carrier and the sound-carrier frequencies. The difference-frequency component will be within the video pass-band of the receiver and will therefore appear as an interference pattern superimposed on the displayed picture. The visibility of this pattern is a function of the amplitudes of the sound signal and the colour sub-carrier at the input to the vision detector. The tests described in this report were carried out in order to assess the attenuation required at the sound-carrier frequency when a colour sub-carrier is present. It should be noted that the appearance of the patterns produced at the display, by this difference-frequency component, is very similar for both the 405-line and the 625-line transmission standards and it is reasonable to assume that the results obtained from this investigation will be applicable to either system.

2. THEORY

If the input to the vision detector of a television receiver contains the vision carrier, the colour carrier and the sound carrier (having frequencies f_v, f_c and f_s respectively), the output of the detector will contain difference-frequency components consisting of:-

$$f_{v-s} = f_v - f_s$$
$$f_{v-c} = f_v - f_c$$
$$f_{c-s} = f_c - f_s$$

The frequency f_{v-s} represents the difference-frequency component between the vision and sound carriers and may be attenuated to be imperceptible at the display tube. The colour sub-carrier f_{v-c} lies within the video pass-band and produces the familiar "dot pattern" at the display. The additional component f_{c-s} also lies within the video pass-band and produces a relatively coarse interference pattern in the form of light and dark stripes.

As stated earlier, the visibility of the latter pattern will depend upon the amplitudes of both the sound signal and the sub-carrier and will therefore be a function of both the sound-trap attenuation provided in the receiver and the saturation of the colour signal. It will also depend upon the amplitude/frequency response of the receiver and upon the propagation conditions, both of which can affect the ratio of the amplitudes of the individual signals.

In order to reduce the visibility of the colour sub-carrier to a minimum, it is normally arranged that its frequency is an odd multiple of half the line-scan frequency.[2] A similar technique has also been employed to reduce the visibility of the sound/sub-carrier interference pattern by arranging that the frequency difference between the sound and vision carriers is an integral multiple of the line-scan frequency. By this means, the visibility of the interference may be reduced some 10 dB[3] compared with that experienced using an arbitrary frequency relationship.

This degree of improvement is, however, only possible when the sound carrier is amplitude modulated; with a frequency-modulated sound signal the minimum visibility condition can only be obtained in the absence of sound modulation.

Intermodulation components may also be produced in the radio frequency, mixer and intermediate-frequency stages of the receiver; this is particularly true for those stages immediately preceding the sound trap, where the signal levels may be high and the ratio of the amplitude of the vision signal to that of the sound signal is only about 7 dB.[4]

3. EXPERIMENTAL ARRANGEMENTS

In order to enable a series of subjective tests to be carried out, equipment was arranged as shown in Fig. 1; the details of the sound and vision carrier frequencies used are shown in Table 1. It will be seen that 405-line colour signals were used in the tests, suitable 625-line signals not being available. A variable attenuator was provided in the sound channel in order to enable the ratio of the amplitudes of the vision and sound signals to be controlled.

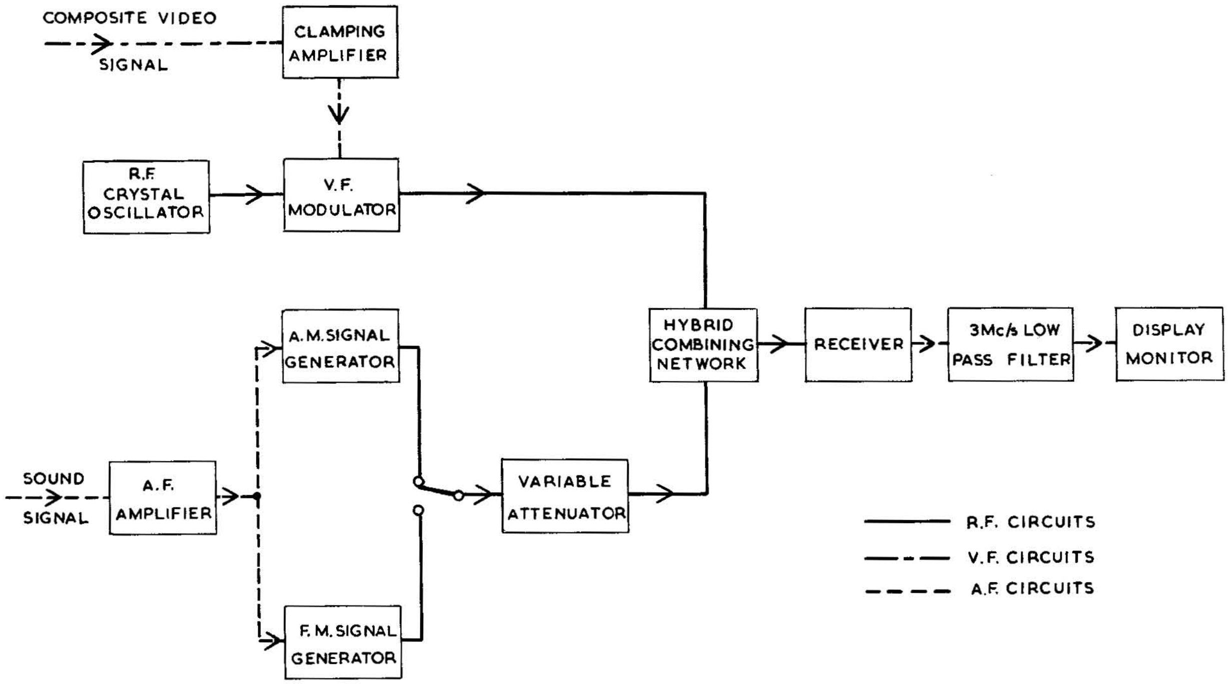

Fig. 1 - Block diagram of equipment arrangement

TABLE 1

Details of Vision and Sound Signals

Signal	Carrier Frequency Mc/s	Modulation Parameters
Vision	61·75	A.M. Negative, by 405-line Monochrome and NTSC-type colour signals (sub-carrier frequency 2·66 Mc/s).
A.M. Sound	65·25	100% peak modulation
F.M. Sound	65·25	50 kc/s peak deviation

The receiver used was a domestic monochrome receiver of continental manufacture designed for the 625-line system.[4] However, the receiver circuits were adjusted so that the amplitude/frequency response was as shown in Fig. 2; it will be noted that in these conditions the attenuation of the sound trap was the recommended 26 dB and, at the chrominance sub-carrier frequency, the response was about 3 dB below the value for the flat portion of the main vision sideband. The output from the vision detector was taken to a 405-line picture monitor via a low-pass filter that provided an attenuation of 12 dB at the sound-to-vision difference frequency f_{v-s}.

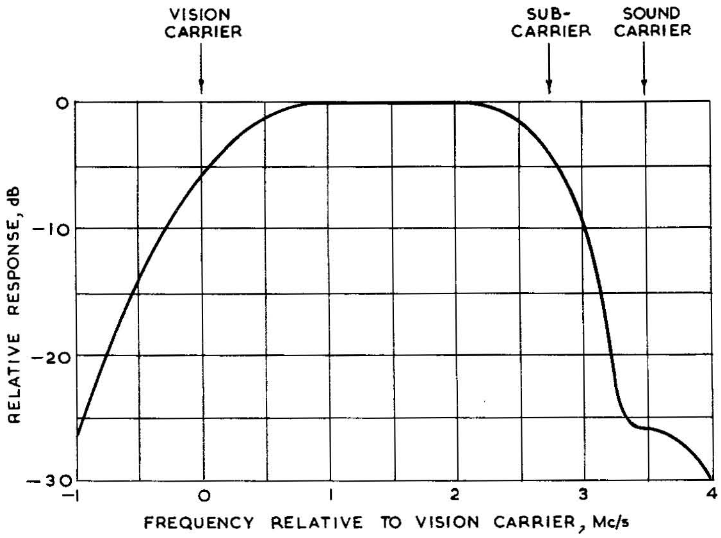

Fig. 2 - Amplitude/frequency response of receiver

Groups of observers were arranged at normal viewing distances from the display and were asked to assess the impairment of the picture, in terms of the subjective scale shown in Table 2, as a function of the effective sound-trap attenuation preceding the receiver vision detector.

TABLE 2

Scale of Subjective Assessment

Grade	Description
1	Imperceptible
2	Just Perceptible
3	Definitely Perceptible but not Disturbing
4	Somewhat Objectionable
5	Definitely Objectionable
6	Unusable

It should be noted that during the tests the sound-trap attenuation in the receiver remained constant at 26 dB and the variations of the effective attenuation were obtained by adjusting the sound-to-vision amplitude ratio at the input to the receiver.

The peak-white brightness of the display was adjusted to be about 15 foot-lamberts (165 asb) and the pictures were viewed in an ambient illumination of approximately 0·5 foot-lamberts (5·5 asb) reflected from the surface of the cathode-ray tube. The maximum contrast range was thus 30 to 1.

The tests were carried out using both monochrome and colour signals, both forms of vision signal being accompanied by either amplitude- or frequency-modulated sound signals. In the case of the colour signals, the pictures were derived from slides, motion-picture films, cameras and electronically generated colour bars; the colour saturation of these pictures did not exceed 75%. The sound carrier was modulated by a programme of continuous light music.

4. RESULTS

The subjective tests were carried out with received signal-to-noise ratios representing both "first-class service-area" and "fringe-area" conditions. It was found that the amplitude of signal at the input to the receiver had little effect upon the results obtained. These are shown in Fig. 3, in which curves have been plotted for the extreme cases of high colour saturation (75%) and monochrome (no colour sub-carrier) with both frequency- and amplitude-modulated sound. The ordinates represent the mean subjective grades, as voted by the observers, and the abscissae represent the corresponding effective sound-trap attenuations, assuming a sound-to-vision amplitude ratio of -7 dB at the input to the receiver.

The points A, B, C and D on the curves represent the subjective grades of interference that may be expected using present-day monochrome receivers; the results are summarised in Table 3. It will be seen that with the introduction of a colour-television service including a frequency-modulated sound transmission, there would be severe impairment of the picture displayed on those monochrome receivers having a sound-trap attenuation conforming to the currently-accepted design practice of 26 dB. Because of the time-varying nature of the pattern such interference is particularly objectionable. On the other hand, with amplitude modulation of the sound carrier and a sound-trap attenuation of 40 dB there would be negligible impairment of the picture with either monochrome or colour transmissions.

The results shown in the curves are for extreme cases; for many pictures such as those obtained from motion-picture film the saturation may not reach 75%. Nevertheless, colour cameras are capable of producing high-saturation pictures, and it can be assumed that they would provide a considerable proportion of the programme material. The tests carried out using slide and motion-picture films showed that for practical purposes, a sound-trap attenuation of not less than 36 dB would appear necessary in order to prevent serious impairment of the pictures displayed by monochrome receivers during average colour transmissions.

The differences in the results obtained for the two systems are explained by the fact that, in the case of amplitude modulation of the sound carrier, the visibility of the sound/sub-carrier interference can be reduced some 10 dB by arrang-

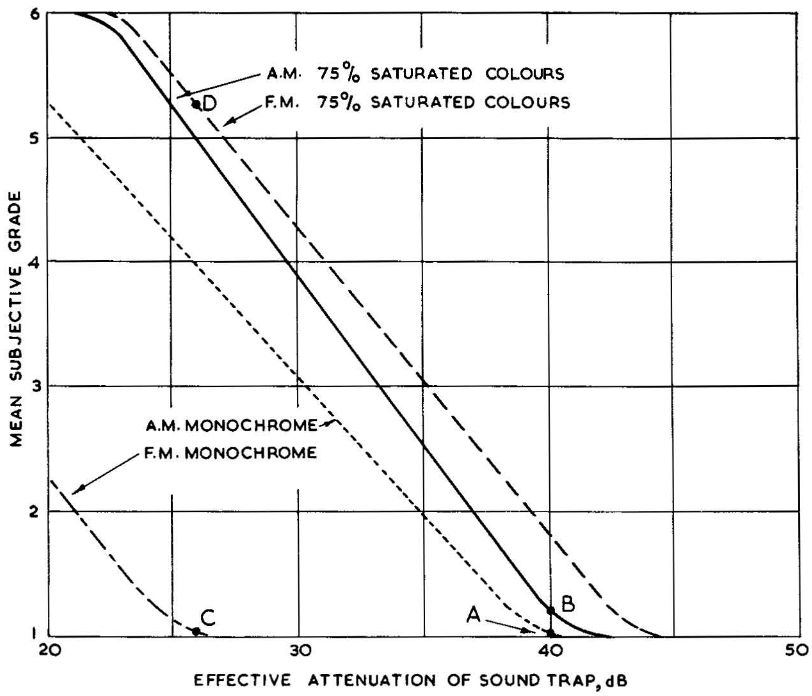

Fig. 3 - Relation between sound-trap attenuation and mean subjective grade of sound signal interference

TABLE 3

Summary of Results for a Typical Receiver

Reference on Fig. 3	Sound Signal Modulation	Attenuation at sound trap	Nature of Picture	Mean Subjective Grade
A	A.M.	-40 dB	Monochrome still picture	1·0
B	A.M.	-40 dB	Colour Bars	1·2
C	F.M.	-26 dB	Monochrome still picture	1·0
D	F.M.	-26 dB	Colour Bars	5·2

ing that the beat frequency is an odd multiple of half the line-scan frequency; with frequency modulation, on the other hand, for which the frequency of the carrier is constantly varying, the half line-frequency relationship cannot of course, be maintained.

The amplitude/frequency response of the receiver will also influence the visibility of the sound/sub-carrier interference. In the receiver used during the tests there was a loss of 3 dB at the chrominance sub-carrier frequency; with receivers designed to exploit fully the available video bandwidth, the impairment would be worse. On the other hand, the interference could be reduced by mistuning the receiver in order to attenuate the sub-carrier, but this would, of course, result in poorer picture resolution. Nevertheless, a conclusion reached by Panel 15 (Receiver Compatibility) of the NTSC[5] implies that receiver retuning be used as a means for reducing the visibility of sound/sub-carrier interference.

5. CONCLUSIONS

If the sound carrier of a television broadcasting system is to be frequency modulated, a sound-trap attenuation of 26 dB in the receiver will be satisfactory only while receiving monochrome transmissions. With the possible introduction of a colour system employing a band-sharing sub-carrier, this attenuation will be totally inadequate and must be increased to at least 36 dB for average colour pictures. This is a degree of rejection comparable with the existing standards required for amplitude-modulated sound transmissions accompanying either monochrome or colour transmissions. It should be noted that in the extreme cases of highly-saturated colour pictures it is necessary to provide some 43 dB to achieve imperceptible impairment to the picture.

6. ACKNOWLEDGEMENTS

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7. REFERENCES

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